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Technical Report 036

COMPARTMENT-TYPE AIR LOCK STUDIES

U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

COMPARTMENT-TYPE AIR LOCK STUDIES

Y-F011-05-327

Type C
Final Report

28 June 1960

by

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U. S. NAVAL CIVIL ENGINEERING
LABORATORY
Port Hueneme, California

OBJECT OF TASK

To develop a portable air lock for use inside buildings in which selected sections are to be protected against contamination from airborne warfare agents.

ABSTRACT

The U. S. Naval Civil Engineering Laboratory was assigned task Y-F011-05-327 to develop a portable prefabricated air lock for interior use and to compare it with the Bureau of Yards and Docks standard portable air lock for exterior use.

Approximately sixty tests were made to determine air lock performances. Most tests were conducted at a building pressure of 0.4 in. of water, with lock air flows varying from 200 to 400 cfm. Other tests were made at varying building pressures and one test was made on an unpressurized building when subject to a simulated 15 mph wind.

Both air locks performed satisfactorily when operated at over 300 cfm. It was determined from these tests, however, that it was difficult and inconvenient to regulate the air flow through the perforated doors of the original NCEL developed lock.

The NCEL air lock was assembled by two men in one hour as compared to the erection of the BuDocks lock by two men in 60 hours. The NCEL type lock is easily disassembled and stored while it is not for the BuDocks lock.

The best features of the original NCEL and the BuDocks standard air lock were retained in the final NCEL design.

It is expected that the cost for mass production of the NCEL lock could be about one-half that of the BuDocks lock.

It is recommended that the final design of the NCEL lock be considered satisfactory for BuDocks requirement for interior use.

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INTRODUCTION

The Bureau of Yards and Docks is responsible for protecting personnel at the Navy Shore Establishments against the hazards of ABC (atomic, biological, or chemical) warfare. Protection from ABC warfare aerosols can be obtained for short periods of time by wearing gas masks, but for longer periods it is more desirable to house personnel in gas-tight buildings that have been pressurized slightly with filtered air. This pressurization protects inhabitants from any contaminants that might otherwise infiltrate the building. Previous investigations have shown that internal pressures above 0.2 in. of water successfully prevent infiltration.[1] A pressurized building must be entered through an air lock to prevent pressure loss. The air from the pressurized area is exhausted through the air lock counter to the entering personnel to continually scavenge the lock.

In many instances it is not necessary to pressurize an entire building but only a room or a suite of rooms. The present BuDocks standard air lock is designed primarily for outside use, is of semi-permanent construction, and requires considerable time to erect. NCEL was assigned the task to develop an improved model which could be easily and quickly erected inside buildings, and to compare its operation with that of the standard lock. An air lock using perforated doors and partitions was successfully developed by the Naval Research Laboratory for the Bureau of Ships.[2] The NCEL three-compartment lock evolved from but is smaller than the BuShips design, and it uses perforated hardboard doors which were developed and tested under previous task NY 300 010-11.

DESCRIPTION

Air Locks

The NCEL prototype and BuDocks standard* air locks are basically the same. Each consists of three small compartments separated by doors, and each door has a device permitting the expended air from the pressurized area to sweep through the air lock to remove any contaminated air carried in by entering personnel into its compartments.

*In the Navy Stock Catalog, this air lock is listed as the "Portable Air Lock Chamber," but for consistency and clarity will be referred to in this report as the BuDocks standard air lock.

The NCEL Air Lock

The construction material used in the NCEL prototype air lock was adopted only after careful consideration of other materials. Cardboard, tar paper, building paper, and other inexpensive materials were all investigated and ruled out because: (1) it would not be practical to use them in the shower area, (2) they would be difficult to handle during emergency erection, (3) panels constructed of these materials could accidentally be punctured. If puncture should occur, especially on the inner compartment, the integrity of the protected space might be placed in jeopardy. Plywood was finally chosen.

The NCEL air lock is designed as a kit of prefabricated parts. Unassembled, the shipping package measures 9-ft long, 3-1/2 ft wide, and 1-1/4 ft high with the lock's roof, floor and mounting skids forming the shipping crate (Figure 1). Shipping weight of this package is 650 pounds.

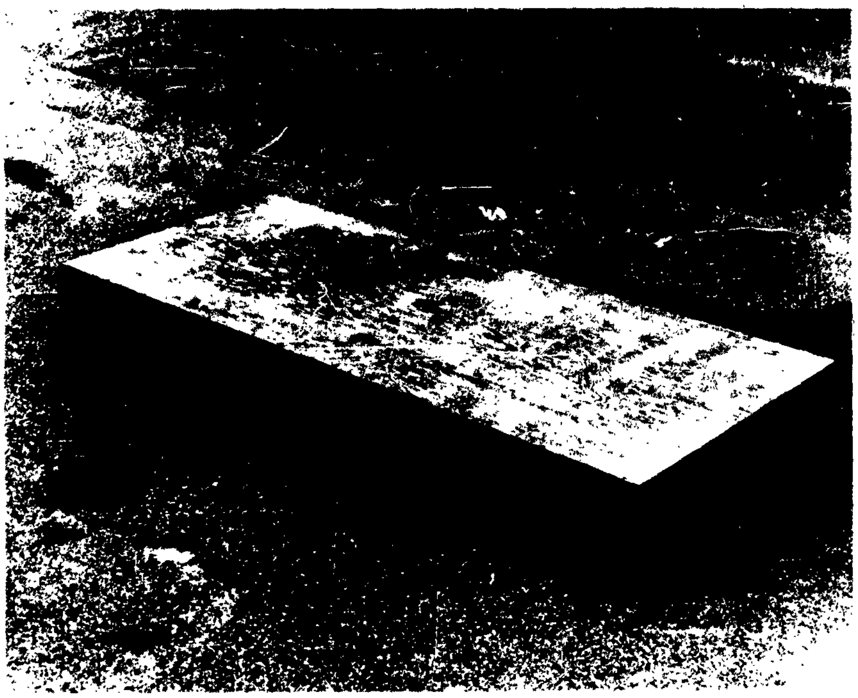


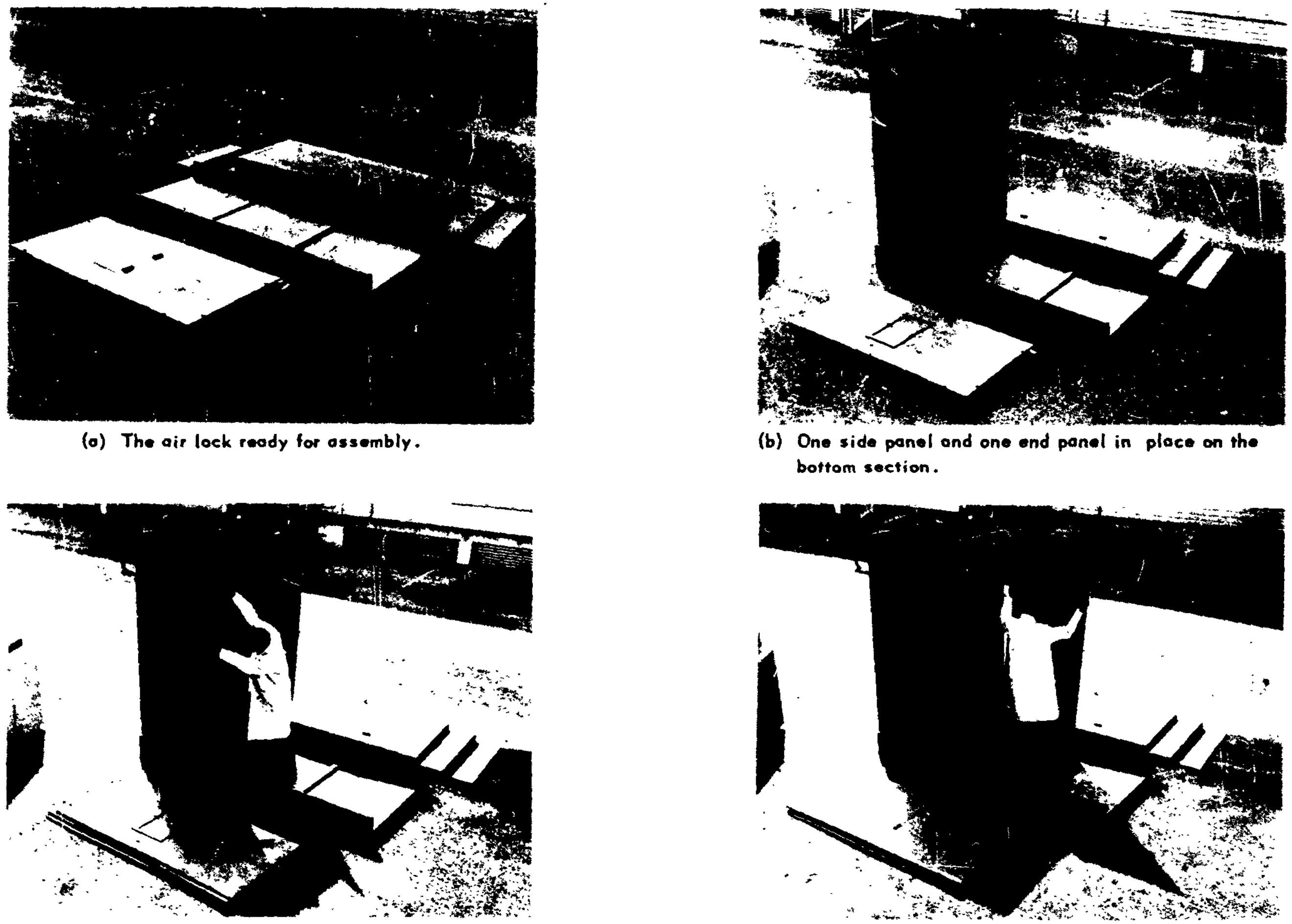
Figure 1. The NCEL air lock as received from the fabricator.

The roof is of 1/2 in., the floor 3/4 in., and the side walls of 3/8 in. exterior grade plywood. When assembled, this air lock measures 9-ft long, 3-1/2 ft wide, and 7-ft high. It consists of three equal-sized, in-line compartments with the center compartment separated from the outer and inner compartments by 1/8-in. perforated hardboard partitions. This same material is used for the lock's end walls as well as entrance, exit and partition doors. Skids and all plywood sections are factory painted. The perforated hardboard, with 1/4 in. holes spaced on 1 in. centers, serves to control the flow of air through the lock. A shower-head assembly and floor drain are provided in the inner compartment with provision for hose connections to the shower and drain. In the side wall of each compartment there is a top-hinged 12 in. by 18 in. pass door for the disposal of contaminated clothing and gas masks. Construction drawings and assembly instructions appear in the Appendix. Using these instructions, two Laboratory technicians easily assembled the lock in about one hour. Figure 2(a) through 2(h) show various stages of erection.

The NCEL final design, Figure 3, is identical to the original design except that the doors and partitions have been modified to include solid material in place of the perforated hardboard. Sliding-gate type air regulators are placed on the inner doors and an anti-back draft valve is placed on the wall of the outer compartment. The outer door is weather-stripped. This equipment is identical to that on the BuDocks lock.

The BuDocks Standard Air Lock

The BuDocks air lock is a standard stock item (C5410-272-9265). It is plywood construction and the unassembled package for shipping measures approximately 15-ft long, 4-ft wide, and 2-1/2 ft high, and its shipping weight is approximately 1450 lbs. Figure 4 shows this package as received from Navy stock. It is skid mounted and when assembled measures 12-ft long, 4-ft wide, and 8-ft high. Like the NCEL lock, it consists of three equal-sized, in-line compartments; but with the outer-compartment end-wall, compartment partitions, and all doors constructed of solid plywood paneling. The inner compartment has no end wall or door, thus this compartment has the same pressure as that in the building. In each partition door there is an adjustable slide-gate air regulator (catalog No. C5670-378-9876). The outer compartment is fitted with a Chemical Corps anti-backdraft damper (catalog No. C5670-378-9857) located on the side wall. These regulators and dampers serve to control the flow of air through the lock. A shower-head assembly and floor drain are provided in the inner compartment with provision for hose connections to the shower and from the drain. Top-hinged pass doors, 14-3/8 in. x 16-3/8 in., are located in the outer and center compartments for disposal of contaminated articles. The lock was assembled and painted by two skilled men in about 60 hours. However, many of the prefabricated parts did not fit properly and had to be reworked or remade and some hardward was missing. Had it not been for these short comings the lock could have been erected somewhat quicker, possibly in 50 hours. Figure 5 is a view of the assembled lock.



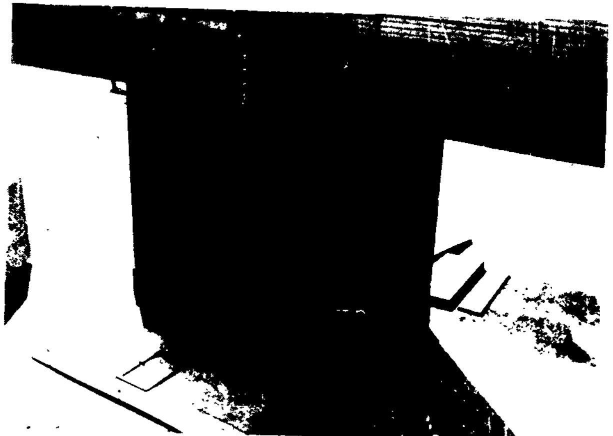
(a) The air lock ready for assembly.

(b) One side panel and one end panel in place on the bottom section.

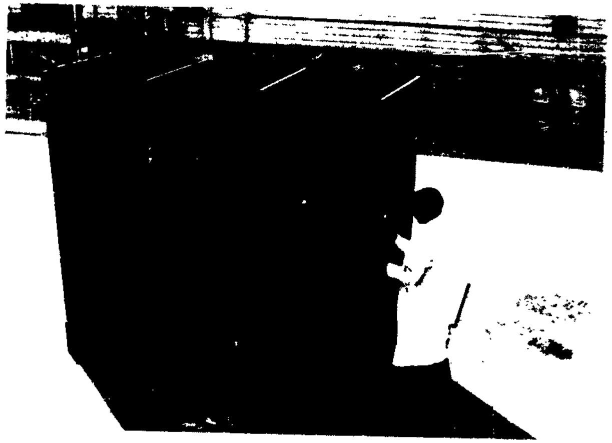
(c) Placing the second door and side panel.

(d) Placing the third side panel.

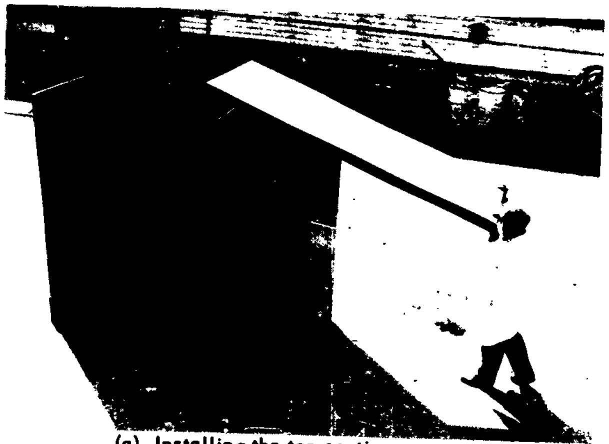
Figure 2. Erection of the NCEL prefabricated air lock.



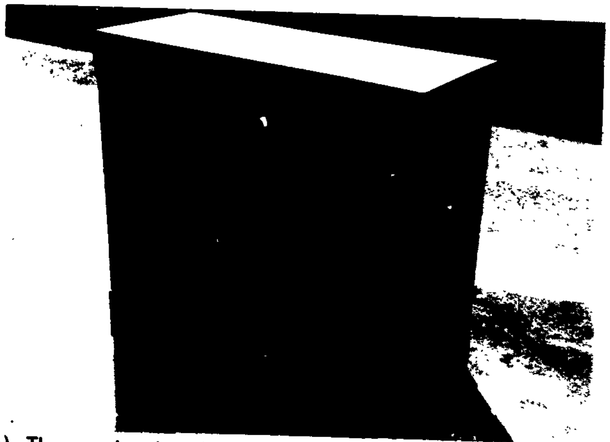
(e) View showing the two completed chambers and the start of the shower compartment.



(f) Placing the end door.



(g) Installing the top section.



(h) The completed air lock with the clothing pass doors shown.

Figure 2. Erection of the NCEL prefabricated air lock. (Cont'd)

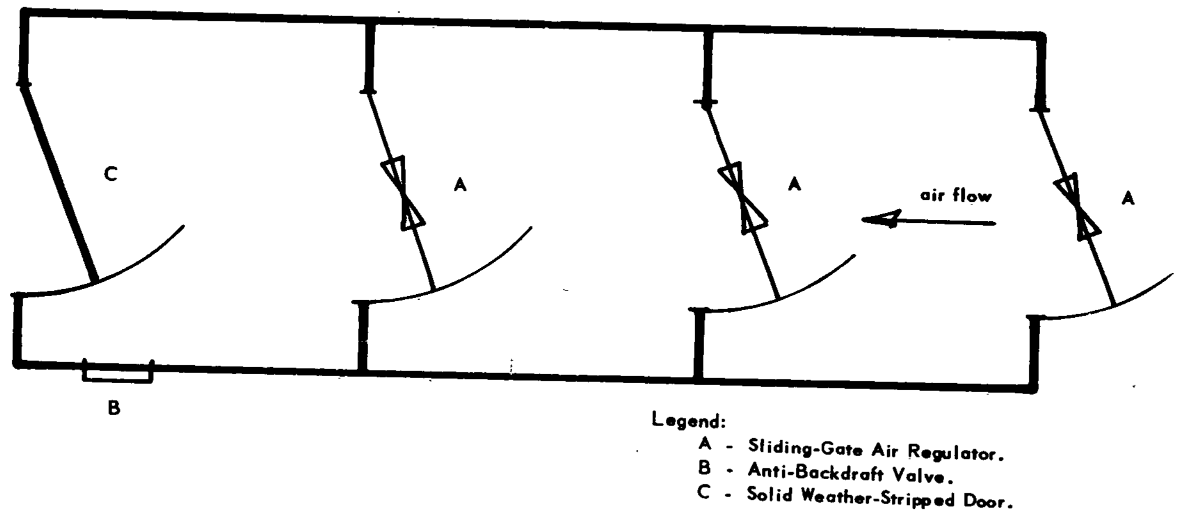


Figure 3. Plan of NCEL air lock (final design).

Figure 4. The BuDocks portable air lock chamber packaged for shipment.

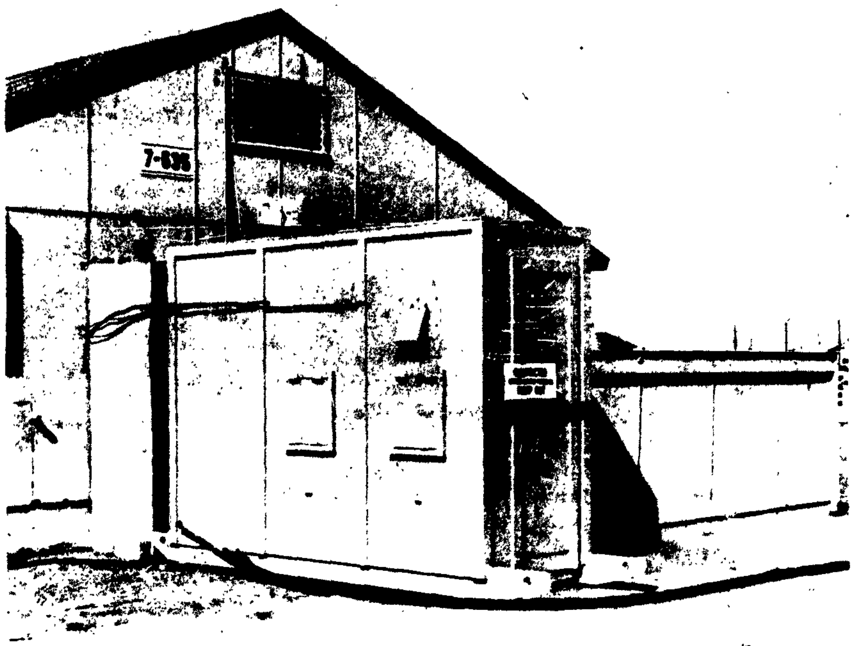


Figure 5. The assembled BuDocks Standard Portable Air Lock.

Test Facility and Instrumentation

A wood-frame building was used in conjunction with the air lock tests. A standard Chemical Corps collective protector, adjustable from approximately 500 to 5000 cfm, was used to pressurize the building.

A zero to 1 in. inclined manometer located within the building was used to measure the inside static pressure. To eliminate rapid fluctuations in the manometer readings caused by wind direction and velocity variations, the lower tap of the manometer was connected to a standard static-pressure tube which in turn was attached to a wind-vane located in an open area adjacent to the lock. Thus, the static-pressure tube always pointed into the wind making manometer readings steady. Figure 6 is a schematic diagram of the pressure measuring system.

The air flow through the NCEL lock was determined by passing the air leaving the lock through a calibrated air-metering duct. Flow measurements through the BuDocks lock were made by placing a vane-type anemometer in the stream of air passing through the innermost sliding-gate regulator.

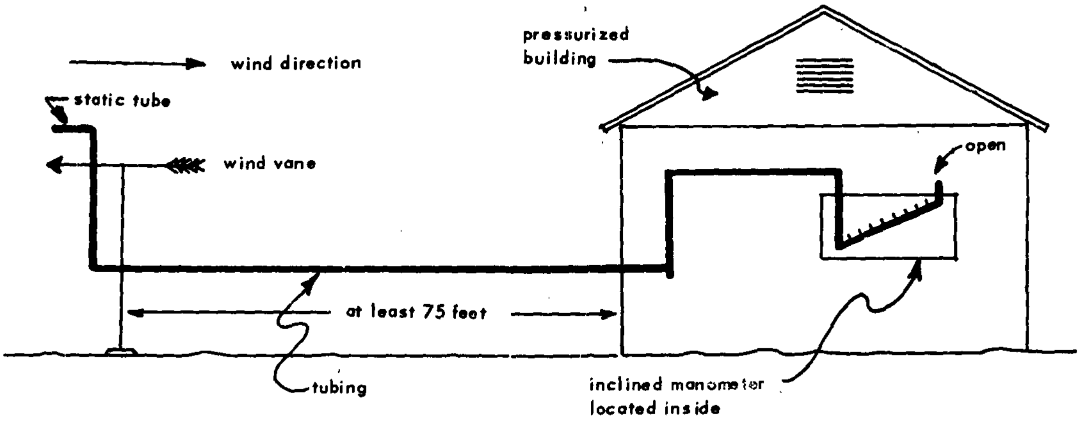


Figure 6. Schematic of equipment used to measure building pressure.

The concentration of the aerosol outside and inside the various air lock compartments was determined with a U. S. Naval Research Laboratory (NRL) Smoke Penetrometer. NRL calibrated this instrument, a light-scattering meter, specifically to measure the intensity of the scattered light from a cloud of Di-Octyl-Phthalate (DOP) smoke. Figure 7 shows this instrument being used to measure concentration in the NCEL lock modified for side exit. Only one instrument was obtained from NRL; this precluded measurements at two or more locations simultaneously.

An aerosol of Di-Octyl-Phthalate was generated at the entrance to the air locks to simulate the contaminated outside air. A Laskin aerosol generator, operated by compressed air, was used to generate the DOP Smoke. Figure 8 shows the aerosol generator at the outer door of the NCEL air lock. This figure also shows the Chemical Corps anti-backdraft damper installed in the outer door, and all holes in the NCEL lock sealed with tape to simulate a solid door.

Figure 7. Checking DOP smoke penetration for NCEL air lock modified for side exit into shelter.

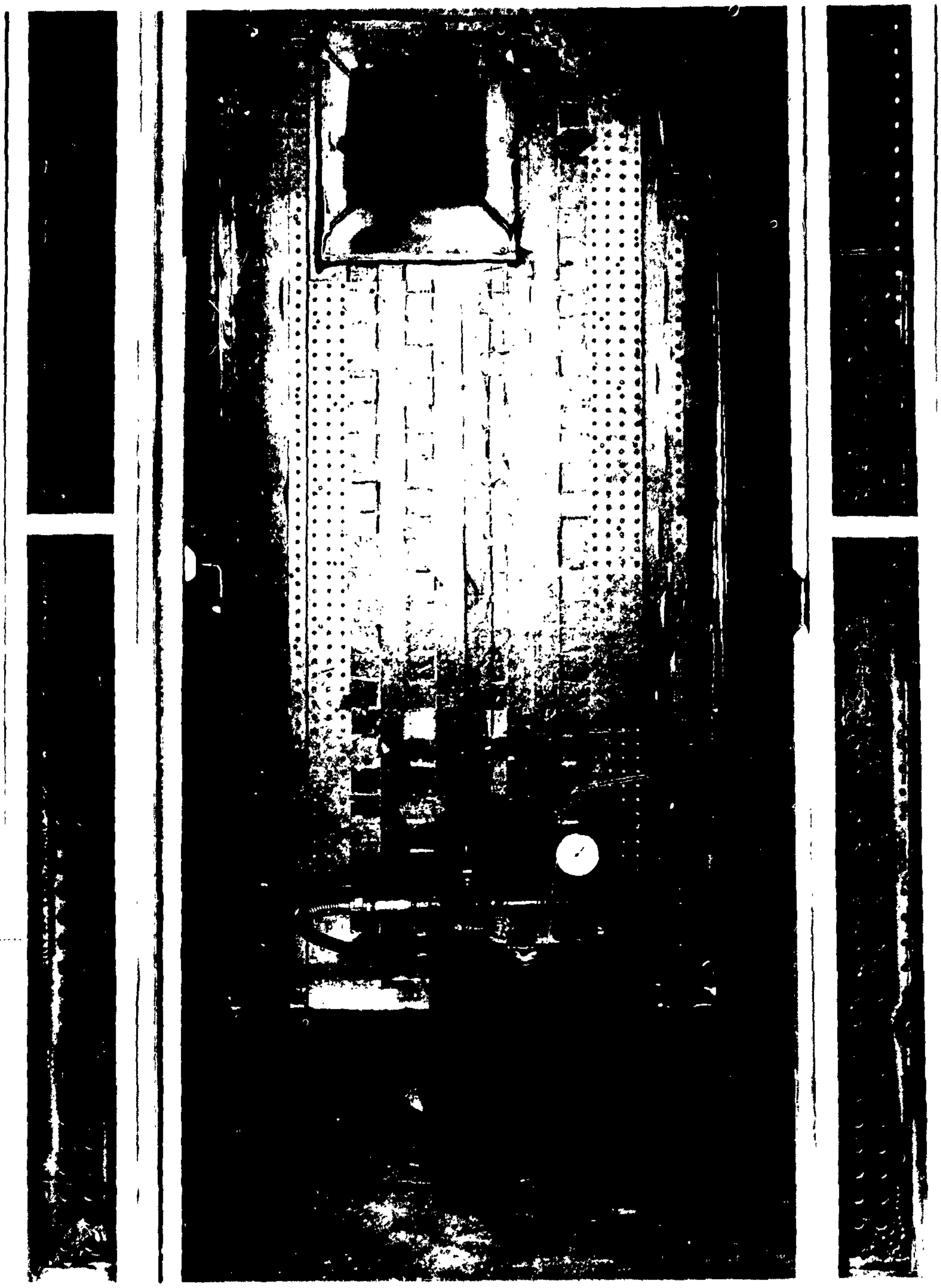


Figure 8. A Laskin type smoke generator at entrance to NCEL air lock.

The desired air flow rates through the air locks at a constant building pressure were empirically obtained. The open area of each air lock door and the pressurizing air flow were alternately varied until the correct air flow through the lock at a building pressure of 0.4" H_2O was obtained. For the original NCEL air lock, the open area in the doors was varied by closing a number of holes (as necessary) in the perforated hardboard. For the BuDocks lock, this only meant adjusting the sliding-gate regulators and the weight on the anti-backdraft valve.

A temporary enclosure was erected about the entrance of the BuDocks lock to maintain required DOP smoke concentration, otherwise the smoke would have been quickly dispersed by the wind (Figure 9). No such enclosure was necessary for the NCEL lock because it was located within the building.

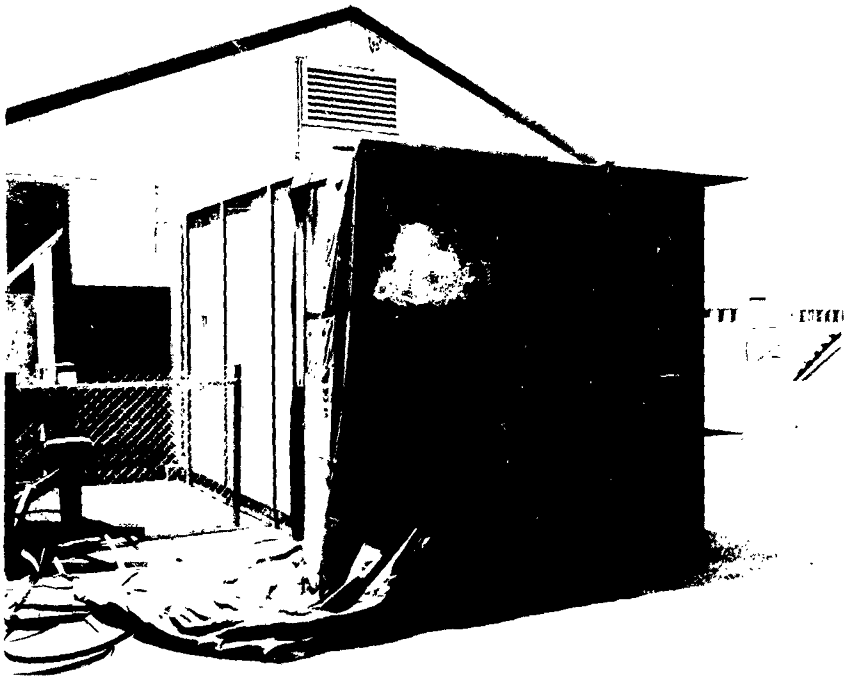


Figure 9. BuDocks lock attached to test building. View shows enclosure around exterior door.

METHOD OF TEST

All outside tests were conducted, as far as practical, during the morning hours of 0800 and 1100 when wind velocity was essentially zero.

The concentration of the DOP Smoke-generated on the outside* of the lock and that penetrating to the various lock compartments was determined for each of the tests performed.

The original NCEL air lock and the BuDocks standard were tested under the following conditions:

1. Without entry of personnel; lock air flows of 200, 300, and 400 cfm; room pressurized to 0.4 in. of water.

2. With single entry (one-man passage); lock air flows of 200, 300, and 400 cfm; room pressurized to 0.4 in. of water. Dwell time in each compartment was 2 minutes.

3. No personnel entry; building pressure rapidly dropped from 0.4 in. of water to zero.

Only the original NCEL lock was further tested as follows:

1. With multiple entry (four-man passage); lock air flow at 200 cfm; room pressurized to 0.4 in. of water. Dwell time in each compartment by each man was 2 minutes.

2. With single entry; lock air flow at 200 cfm; room pressurized to 0.4 in. of water. The exit door of the inner compartment was moved from the end wall to the side of the lock. Lock side exit arrangement would be used in corridors and other narrow or restricted spaces.

3. No personnel entry; no air flow through lock; building pressure at zero static; simulated 15 mph wind. An anti-back draft damper was installed in the entrance door and all perforations in the door and end wall taped shut to simulate a solid door and wall.

Figure 10 is a plan drawing showing the changes made for tests 5 and 6.

*A 100% concentration of a cloud of DOP Smoke can be compared to a ground fog where visibility is extremely limited.

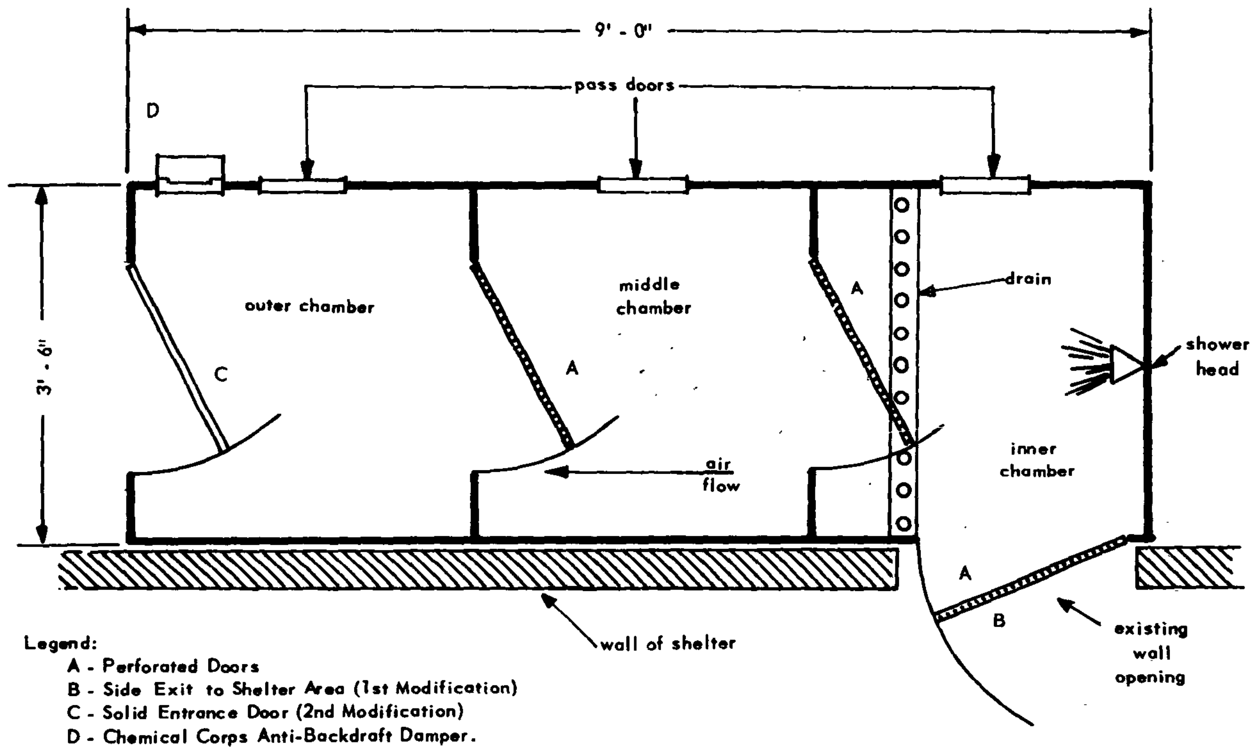


Figure 10. Plan of modified NCEL prefabricated air lock.

The two air locks were also tested in the following manner without the use of DOP Smoke:

1. With the air flow established at 200 cfm for a building pressure of 0.4 in. of water, the effect of a 50 percent variation of building pressure from 0.2 to 0.6 in. of water on air lock flows was measured. The measurements were repeated at 300 and 400 cfm for 0.4 in. of water building pressure.

No tests were performed on the final design of the NCEL air lock because nothing was altered on it except the method of air regulation and this is identical to that used on the BuDocks standard lock.

RESULTS OF TEST

Both the NCEL and BuDocks air locks performed equally well with no personnel entry. Smoke penetration was not measurable in the outer compartments, and this precluded the necessity of checking either the center or inner compartments.

Both locks performed nearly equal in the tests in which single entries were made. Only a trace of smoke was detected in the inner compartment of the NCEL lock at air flows of 200 cfm despite the initial 14 percent concentration in its outer compartment; none penetrated the BuDocks inner compartment. No penetration occurred in either inner compartment at air flow rates higher than 200 cfm. Table I is a resumé of smoke penetration at the given air flow resulting from the passage of one man. Dwell time in each compartment was 2 minutes.

The clearance times of Table I are the times required to clear the compartments to 0 percent with the outside concentration between 90 - 100%. Air flow rates of 200 cfm appear to be the minimum which will prevent infiltration for the tested NCEL lock, but might be less than that for the BuDocks lock and the NCEL final design lock.

In one test in which four men singly filed through the NCEL lock in 2-min. intervals, the penetration of smoke into the inner compartment was insignificant (about 0.01 percent). The concentration in the outer compartment, based on other data, may be expected to have been about 15 percent.

The tests in which the exit door of the NCEL lock was moved from the end to the side of the inner compartment showed that this alteration had no effect on the lock's performance. No penetration was detected in the inner compartment with outer compartment concentrations up to 30 percent.

Table I. Air Lock Performance During Single Entry
(90 - 100% Smoke Concentration and No Wind; 0.4" H_2O Building Pressure)

Type of Lock	Air Flow (cfm)	Outer Compartment		Center Compartment		Inner Compartment	
		Highest Conc. (%)	Clear. Time (min.)	Highest Conc. (%)	Clear. Time (min.)	Highest Conc. (%)	Clear. Time (min.)
NCEL	200	14.0	6.0	0.2	2.0	Trace*	0.5
	300	5.5	3.0	0	-	0	-
	400	4.0	2.0	0	-	0	-
BuDocks	200	3.5	3.5	Trace*	2.0	0	-
	300	3.0	3.5	0	-	0	-
	400	6.7	2.5	0	-	0	-

*About 0.01%

The test with a simulated 15 mph steady wind blowing against the solid outer door of an air lock attached to an unpressurized building showed the need for good lock sealing. Without the door joints sealed, the smoke penetrated through the air lock to the building interior to a concentration of 6 percent in 8 minutes. With the door joints sealed, the penetration was only 1 percent in 11 minutes.

When the building pressure was rapidly reduced to 0 in. of water (atmospheric), smoke infiltrated quickly in the outer compartments of both locks. Data from these tests were extremely scattered but generally concentrations of the order of 10 to 30 percent appeared in the outer compartments within 1 minute. The rate of infiltration through the locks depended largely on the settings of the air flow regulators. Rates were less at the 200 cfm adjustment than for higher air flows. In most cases smoke was detected in the inner compartments within 5 min. at the 400 cfm setting.

Table II shows the effects of a 50 percent building pressure variation on lock air flow rates from an initial stabilized condition.

Table II. Effect of 50 Percent Building Pressure Variation on Air Lock Flow Rates in cfm

Air Lock Type	Degree of Building Pressurization	Actual Building Pressure ("H_2O)	Lock Air Flow (cfm)		
NCEL Original	Minus (-) 50%	0.2	90	160	200
	Initially established	0.4	200	300	400
	Plus (+) 50%	0.6	270	350*	440**
BuDocks Standard	Minus (-) 50%	0.2	130	190	230
	Initially established	0.4	200	300	400
	Plus (+) 50%	0.6	246	370	505

*0.55" H_2O actual building pressure. (This was the limit of the pressurization equipment)

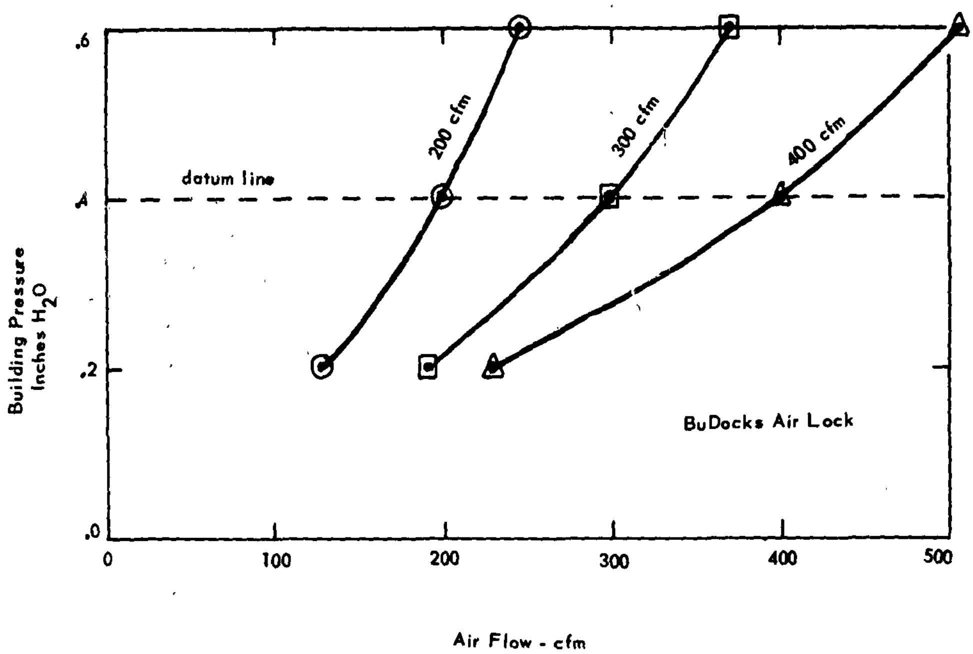
**0.49" H_2O actual building pressure. (This was the limit of the pressurization equipment)

The above Table II is graphically represented by curves of Figure 11. If air flow rates below 200 cfm would permit infiltration, and tests indicated this may happen, then the lock should not be operated below 300 cfm if a pressure drop to 0.2 in. water is a possibility.

DISCUSSION OF RESULTS

It has been previously mentioned that most tests were conducted during morning hours when the outside air was calm. Although the wind measuring instruments read zero, undetectable air currents would sometimes create slight negative or positive pressures around the building. These eddies affected air flow through the lock, and thus caused erratic smoke concentration readings.

The NCEL lock is easy to erect, and it may be assembled and disassembled many times without appreciable wear to mating sections. Air flows through the NCEL lock could not be readily altered because the free-area of the perforated hardboard is fixed by hole size and center spacing. Improvement can be made by replacing the perforated with solid hardboard, by installing BuDocks-type sliding gate regulators in partition doors, and by placing an anti-back draft damper in the outer compartment wall. The entrance door should be weather-stripped.



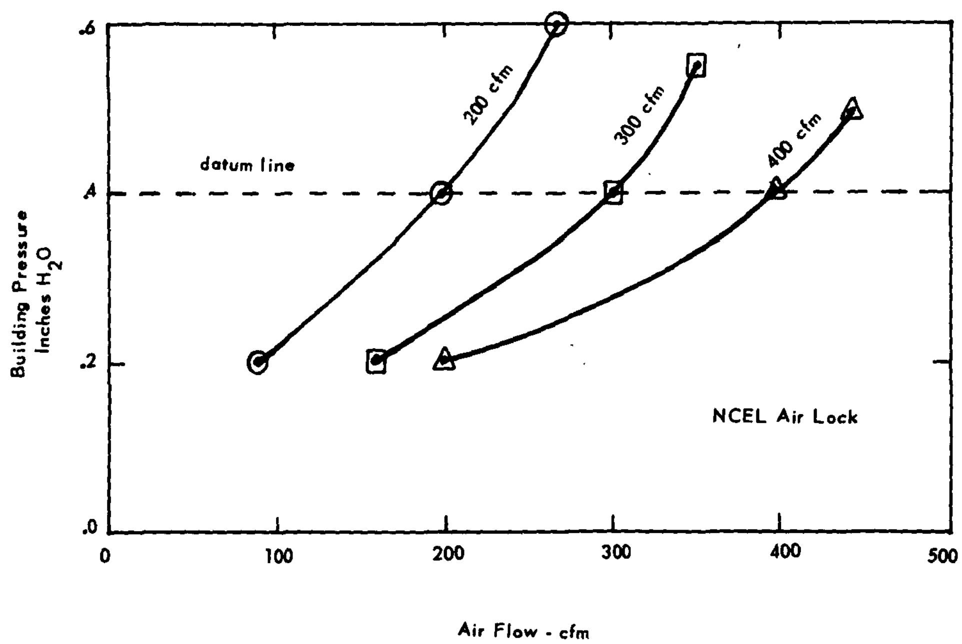


Figure 11. Air flow variations caused by change in building pressure.

CONCLUSIONS

1. The NCEL lock is easy for unskilled men to erect quickly, while considerable skill, time and effort is required to erect the BuDocks standard lock.

2. Scavenging characteristics of both locks are satisfactory at building pressures of 0.4 in. of water with 200, 300 and 400 cfm air flow rates through the locks.

3. The air flow through the original NCEL lock was not easily regulated because it was difficult and inconvenient to adjust holes in the perforated material.

4. The air flow through the BuDocks standard air lock was easily regulated by making simple adjustments to the sliding-gate air regulations and the anti-back draft valve.

5. Neither lock offers safety at air flow rates below 300 cfm at building pressures of 0.2 in. of water or less.

6. Neither lock would prevent the entrance of contaminated air if building pressure was suddenly reduced to zero and wind velocity was in excess of 15 miles.

7. Moving the exit door to the side of the lock would have no effect on the performance of the lock.

8. The final NCEL design, which incorporates the favorable features of both the BuDocks standard and the NCEL original air lock, should satisfactorily meet all performance standards since it incorporates the knock-down-type prefabricated construction of the NCEL original lock and the anti-back draft valves and sliding-gate air regulators of the BuDocks standard lock.

RECOMMENDATION

It is recommended that the NCEL air lock be adopted by BuDocks for interior use.

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2. Young, J. A., J. K. Thompson, and E. N. Hellberg, "Corridor-Type Air-lock Studies," U. S. Naval Research Laboratory, Memorandum Report 765, December 1957.

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6. L. M. Buchanan, H. M. Decker, and R. W. Porter; "BW Evaluation of Shelter Components at Port Hueneme, California, July 1956," Memorandum Report No. 1-57, (Conf.); Camp Detrick, Maryland, Personnel Protection Branch; 24 September 1956.

7. BuDocks letter D442A/THM:rjw NY 300 006-2 of 7 Feb 1957.

8. H. W. Knudson and L. White; "Development of Smoke Penetration Meters," Report No. P-2642; U. S. Naval Research Laboratory; 14 September 1945.

APPENDIX

SPECIFICATIONS

PORTABLE ENTRANCE AIR LOCK

1. SCOPE:

   1.1 Scope: This specification covers the materials and method of manufacture of portable entrance air lock.

2. SPECIFICATIONS:

   2.1 Drawings: The following drawings form a part of this specification:

HS-1000	HS-1100
HS-1001	HS-1101
HS-1002	
HS-1003	
HS-1004	

3. MATERIAL: Shall conform to the following:

   3.1 Plywood: The plywood used shall be exterior type Douglas Fir, sanded two sides, Grade A-C or better, conforming to Specification MIL-P-66.

   3.2 Lumber:
   3.2.1 Skids: Shall be Douglas Fir - surfaced four sides.
   3.2.2 Lumber used for balance of unit shall be Pine or Douglas Fir.

   3.3 Fiberboard: Shall have a smooth surface on two sides, be treated and perforated.

   3.4 Hardware: Shall be of Commercial type.

   3.5 Drain: Shall be of Steel, welded and galvanized.

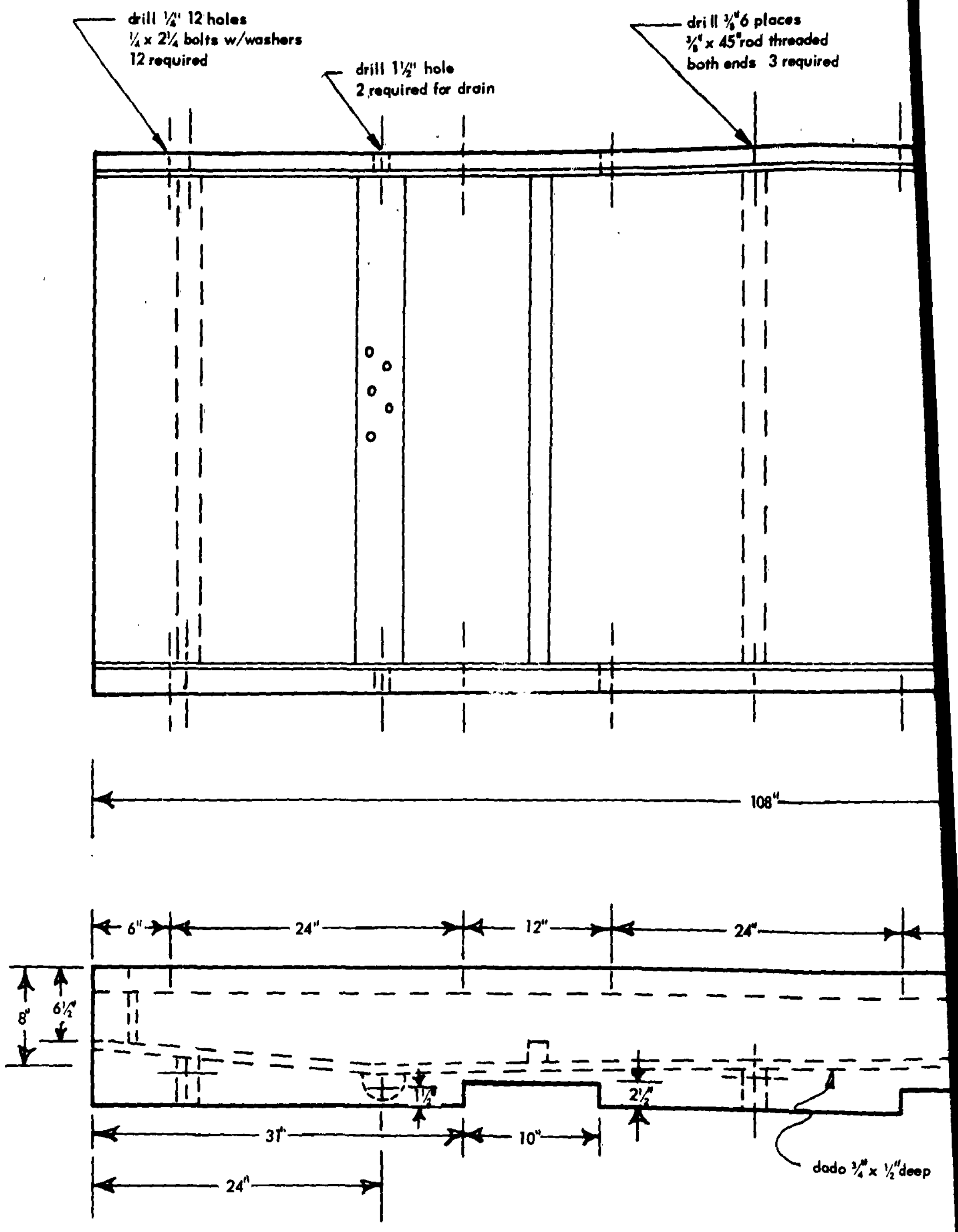
4. CONSTRUCTION:

   4.1 Door Panel assemblies shall be interchangeable.

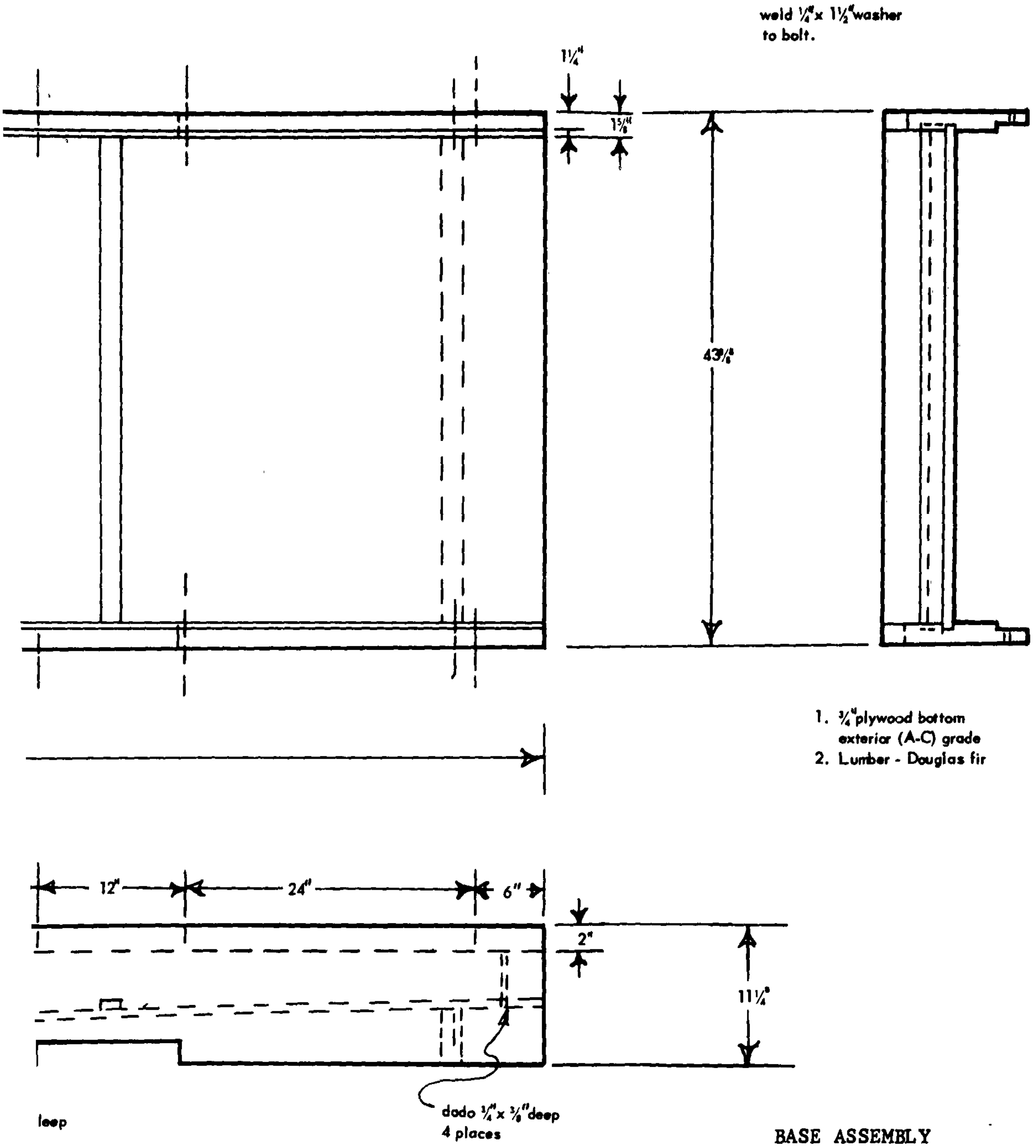
   4.2 Wall Panels shall be interchangeable.

   4.3 Top shall be symmetrical.

   4.4 Surfacing: All exposed surfaces shall be cleanly and smoothly surfaced.

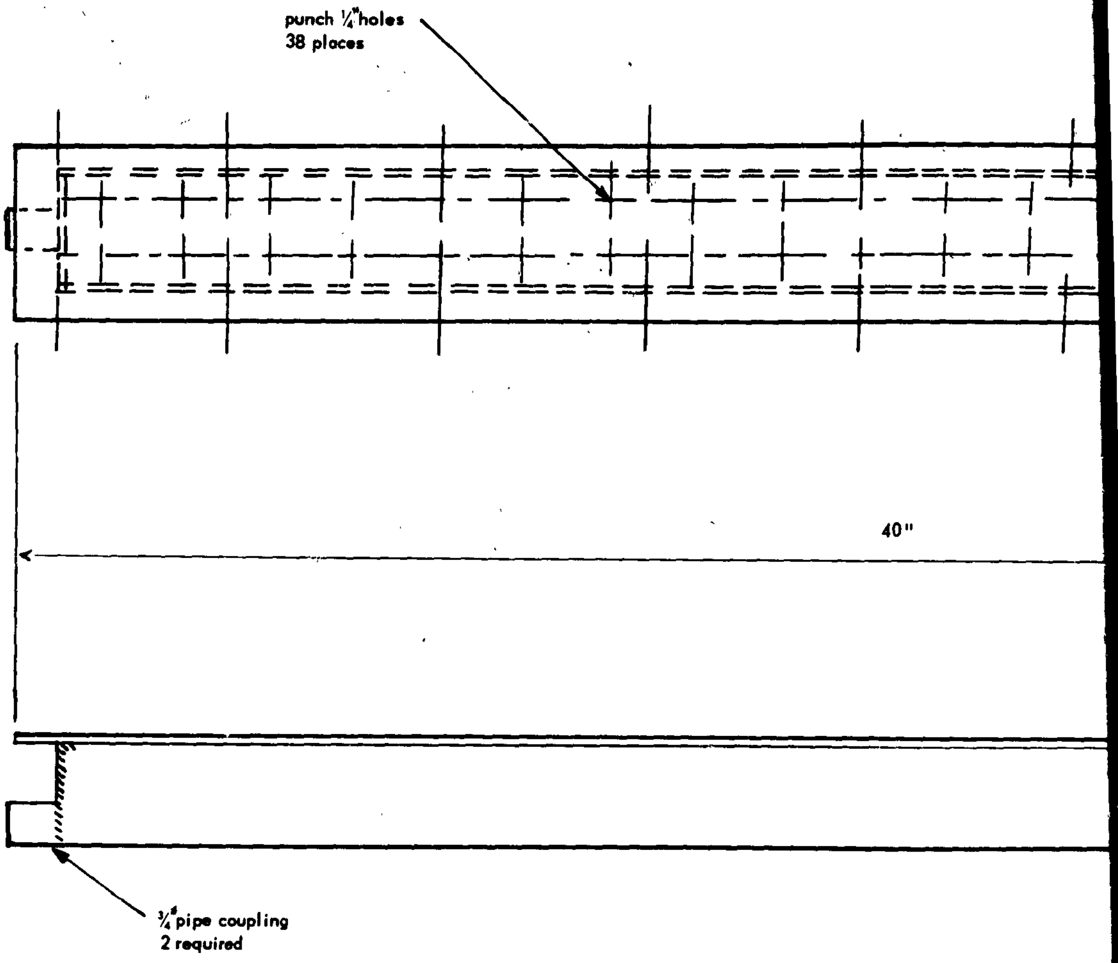

drill 1/4" 12 holes
1/4 x 2 1/4 bolts w/washers
12 required
drill 1 1/2" hole
2 required for drain
drill 3/8" 6 places
3/8" x 45" rod threaded
both ends 3 required
108"
6"
24"
12"
24"
8"
6 1/2"
1 1/2"
2 1/2"
31"
10"
24"
dado 3/4" x 1/2" deep

1



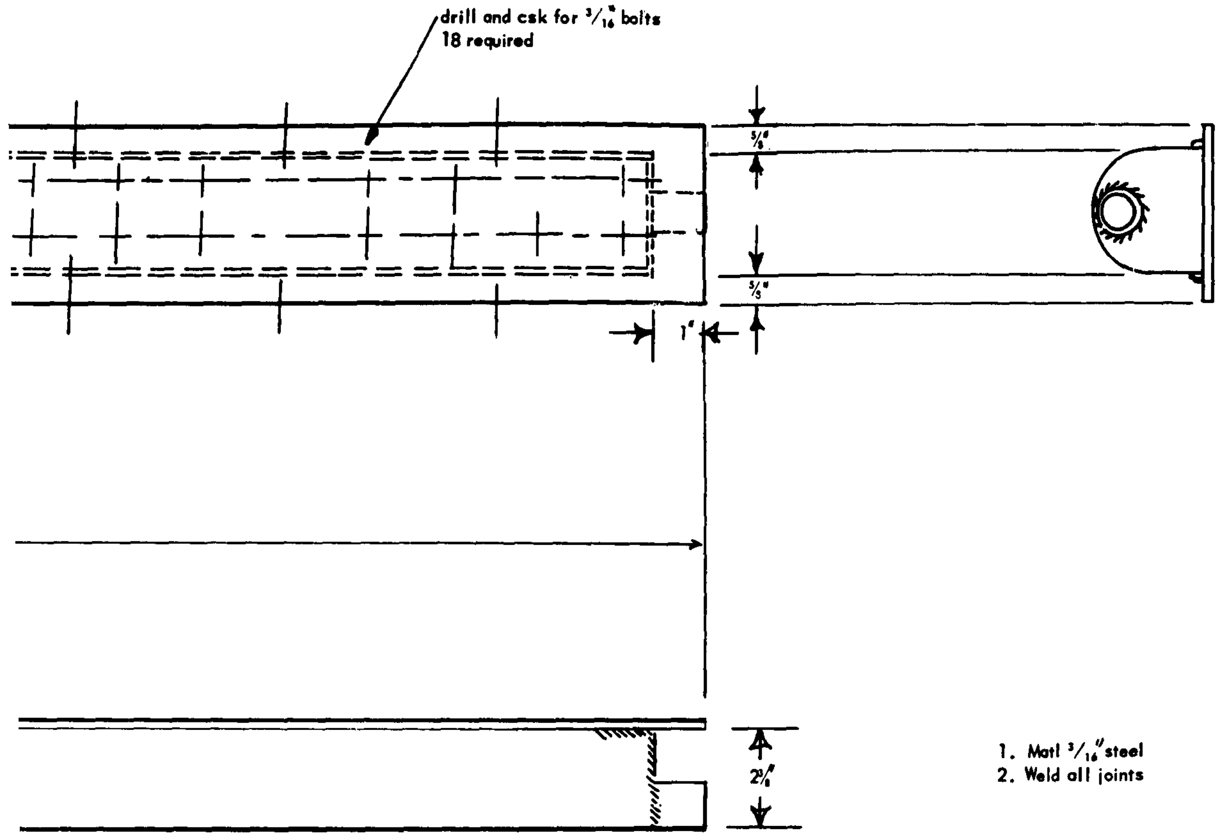
BASE ASSEMBLY
AIR LOCK

Hardwood Specialties Drawing No. HS 1000



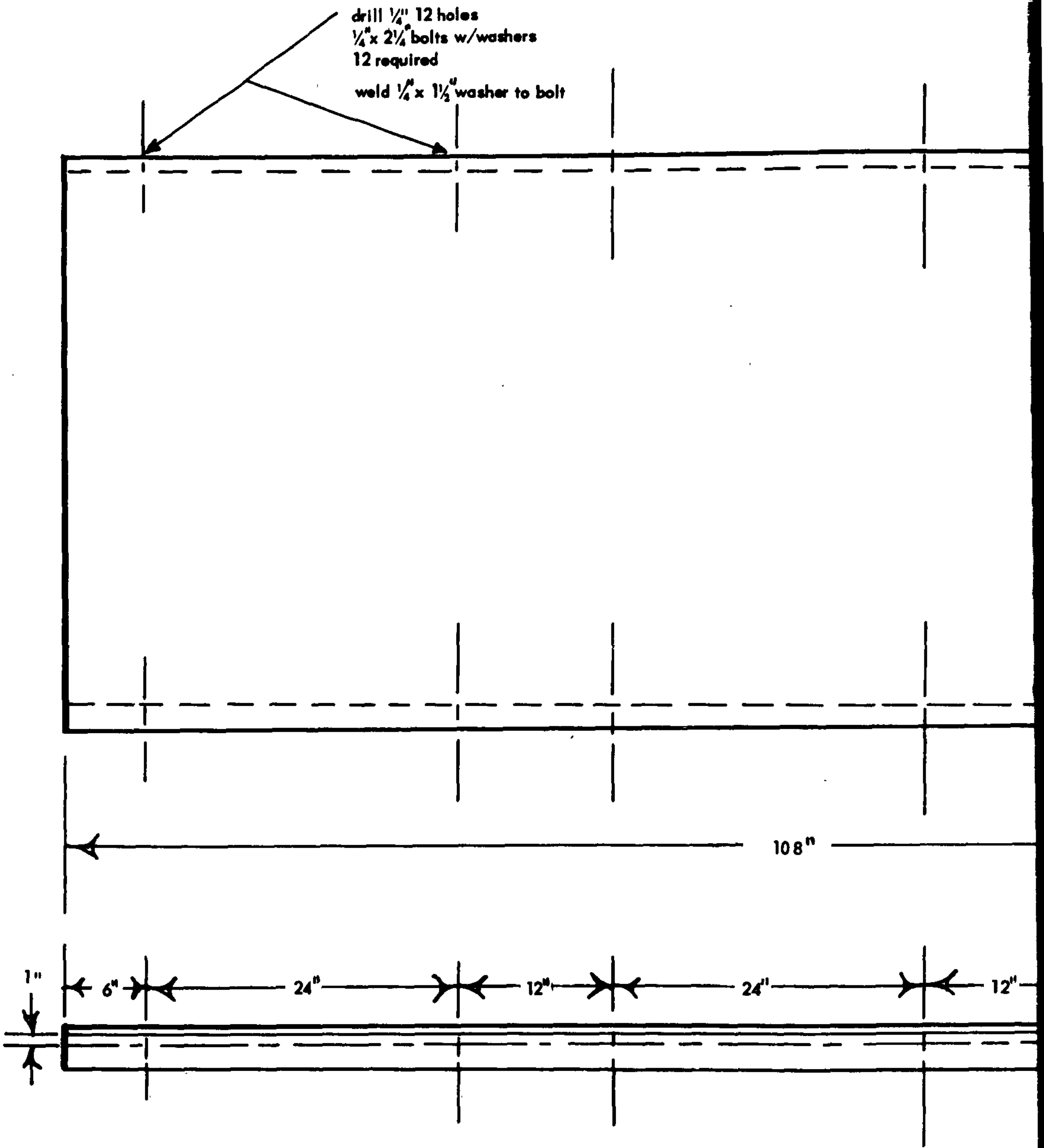
DRAIN A
AIR

Hardwood Specialties



DRAIN ASSEMBLY
AIR LOCK

:ialties Drawing No. HS 1001



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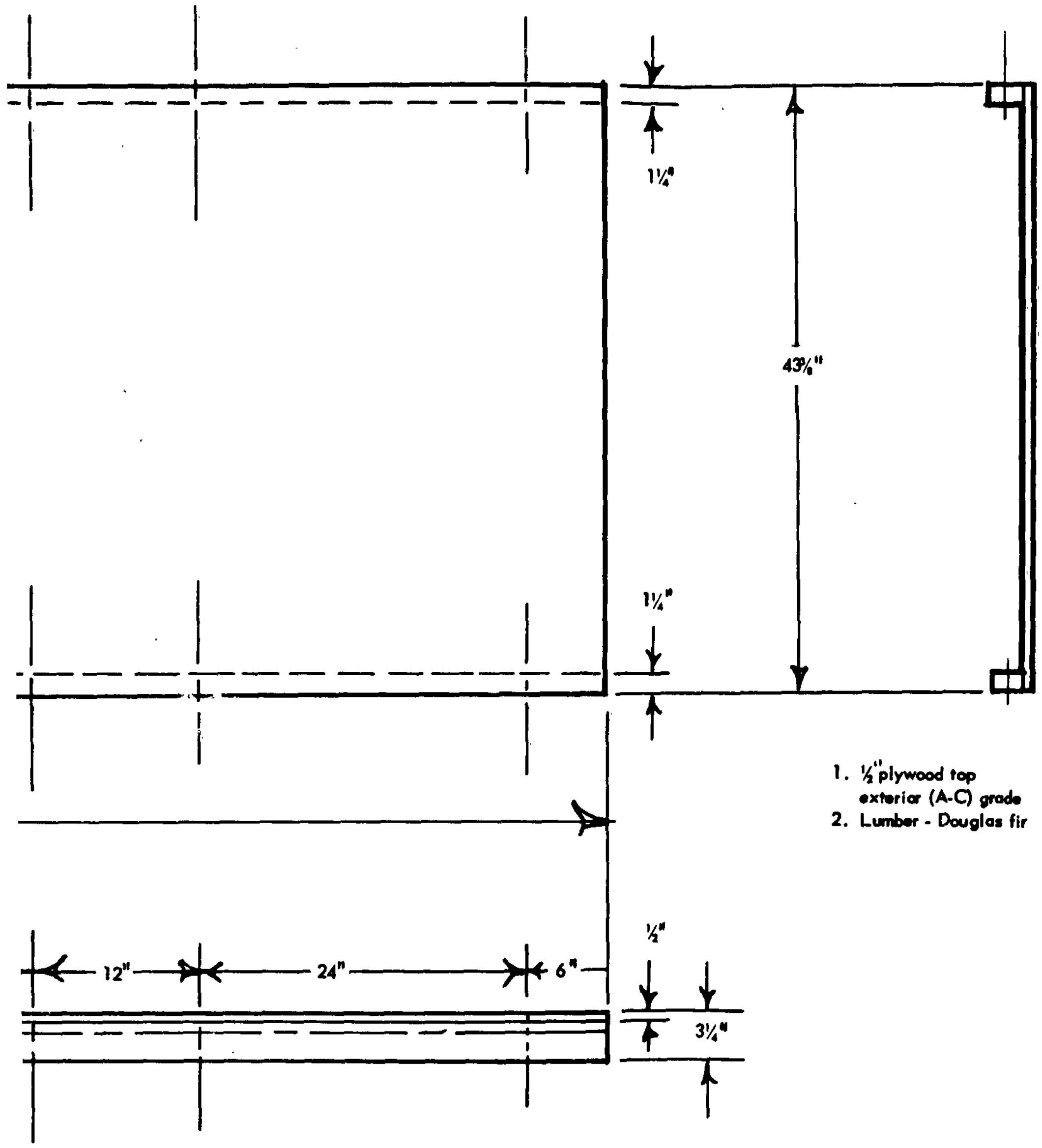
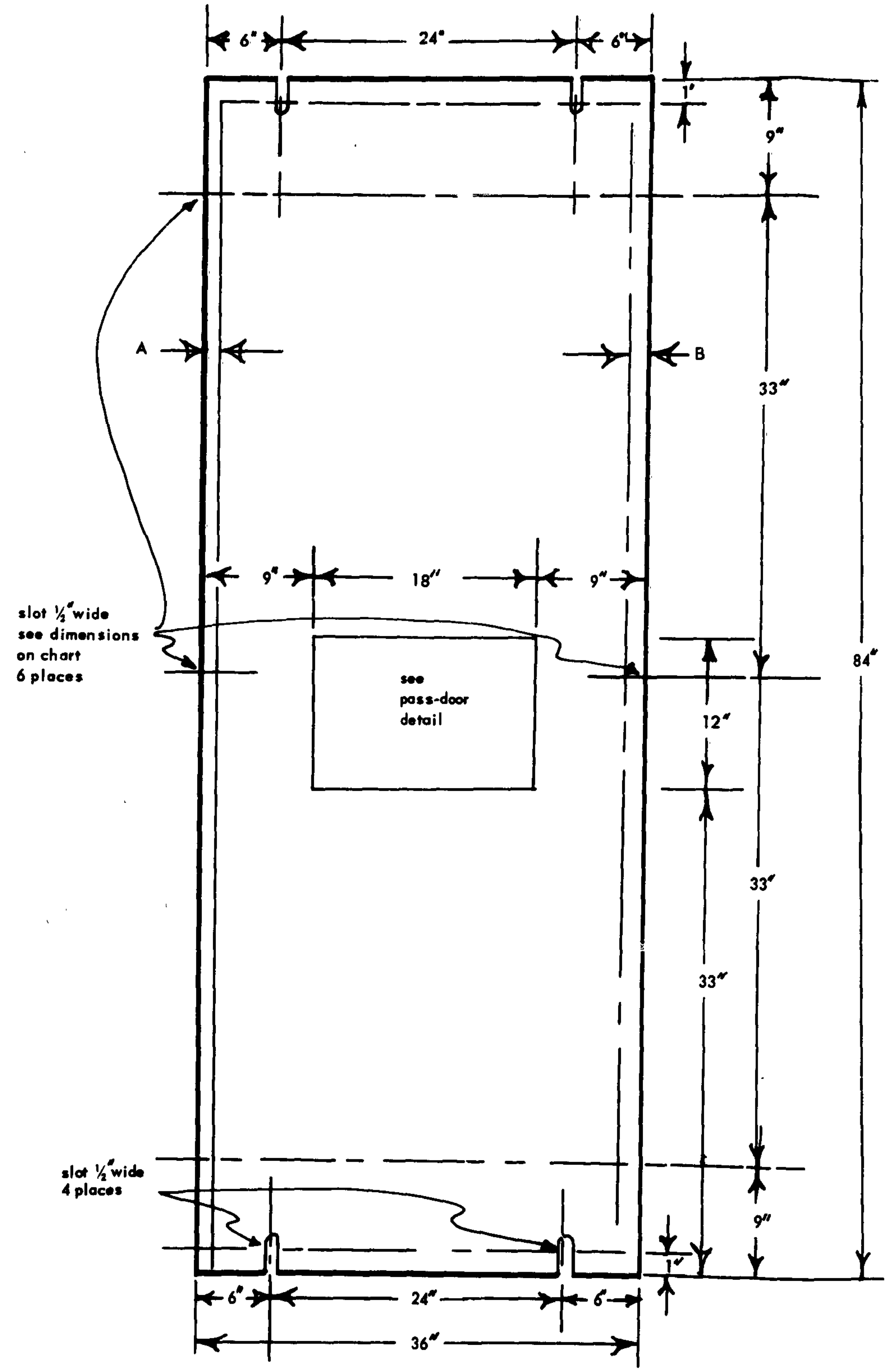
TOP ASSEMB
AIR LOCK

Hardwood Specialties Dra



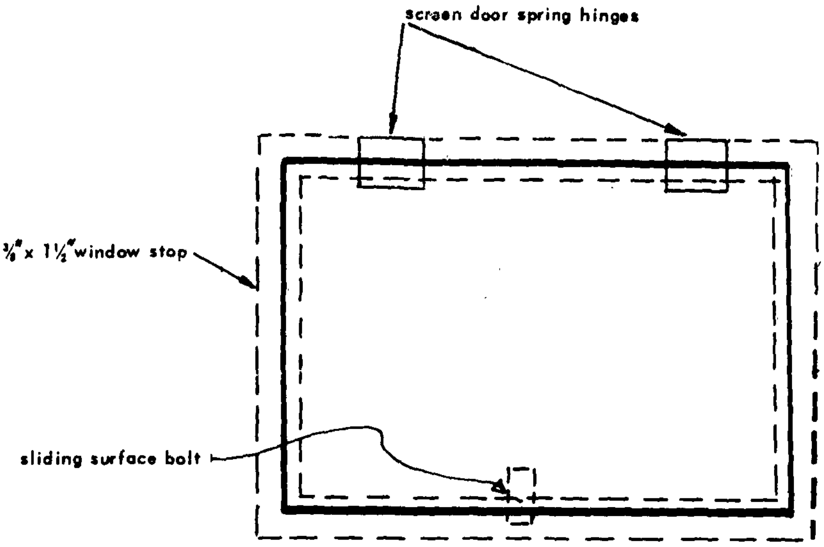
[TOP ASSEMBLY
AIR LOCK

[...]lties Drawing No. HS 1002



1

plywood ⅜ A-C exterior



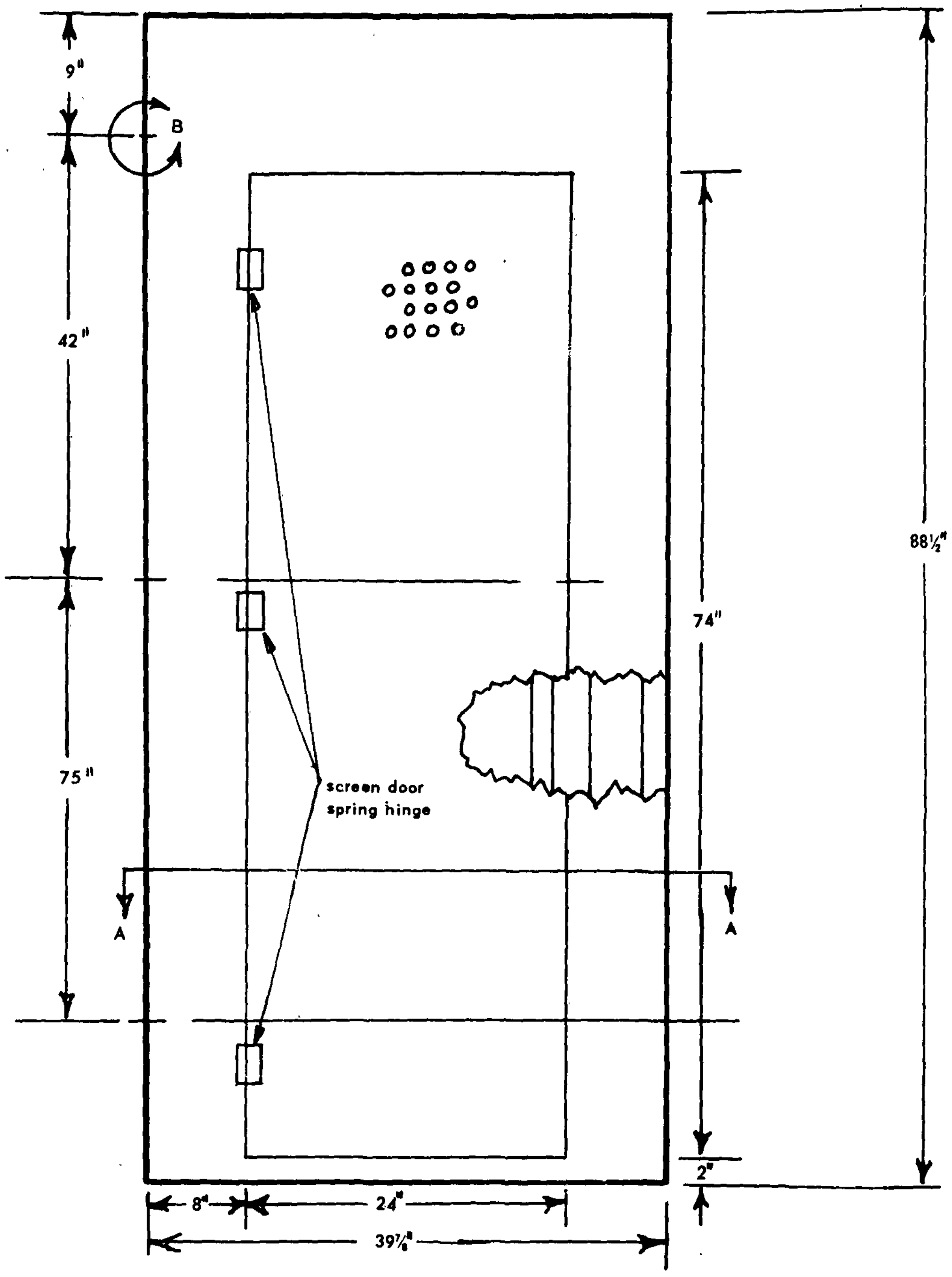
doors must swing to the outside

Panel No	Pass Door	A Dim	B Dim
A	yes	3/4"	1/4"
B	yes	1/4"	1/4"
C	yes	1/4"	3/4"
D	no	3/4"	1/4"
E	no	1/4"	1/4"
F	no	1/4"	3/4"

2

WALL PANELS
AIR LOCK

Hardwood Specialties Drawing No. HS 1003



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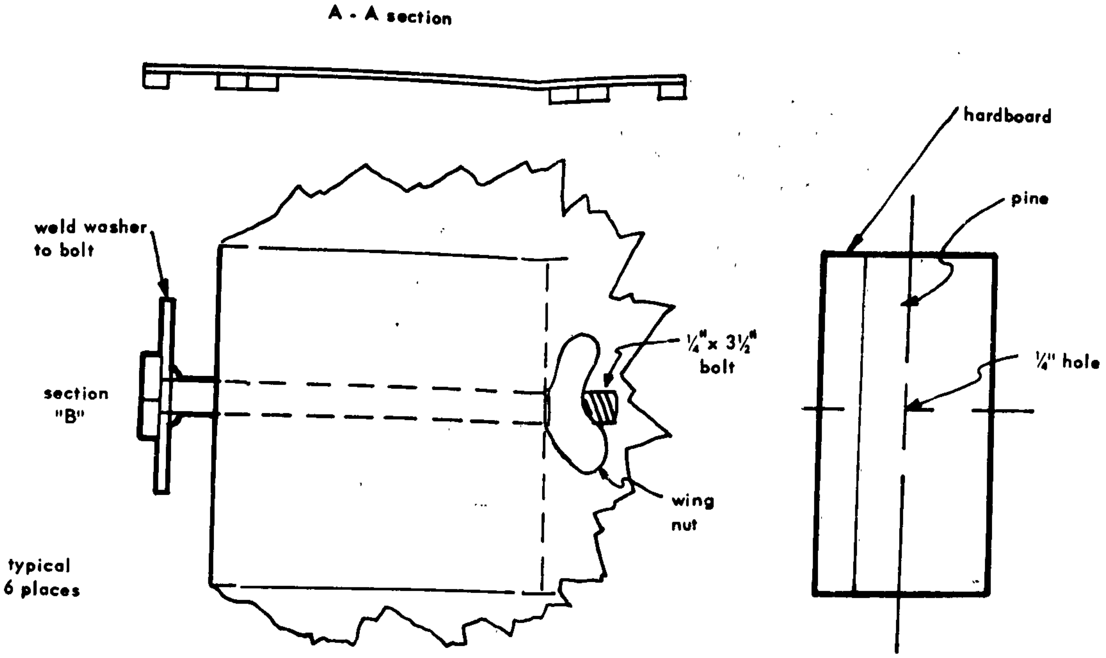
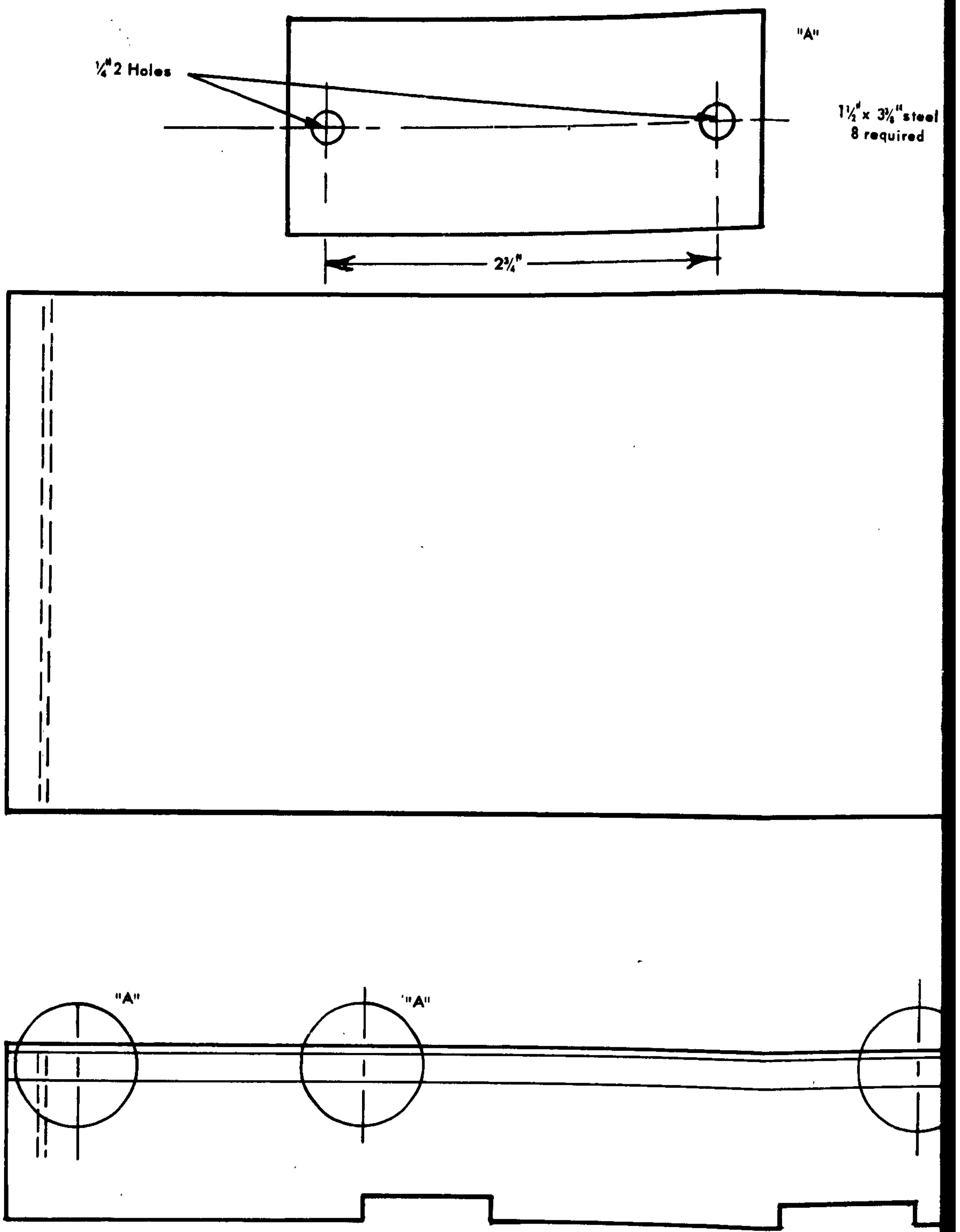


NOTES:
Face of door panel-perforated hardboard lumber ¾" thick pine, 2" wide. Doors shall swing in the direction of air flow.

2

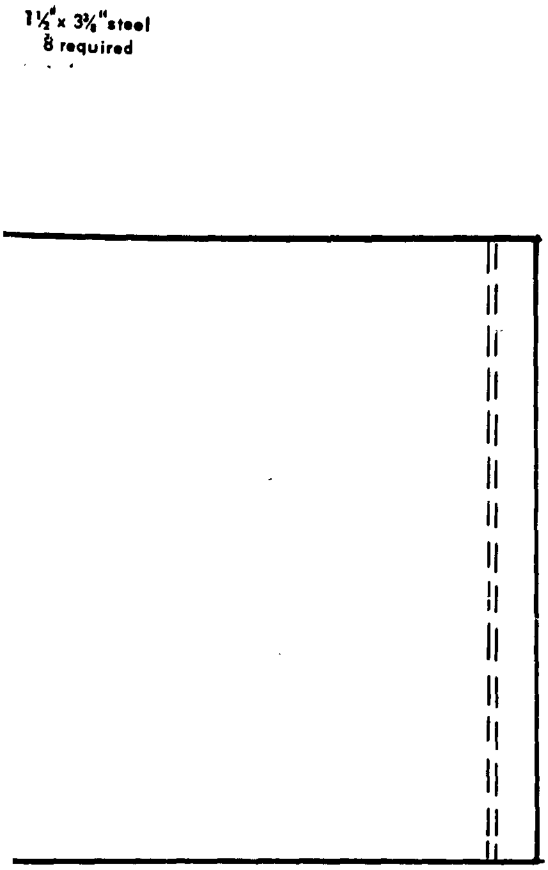
DOOR PANEL ASSEMBLY
AIR LOCK

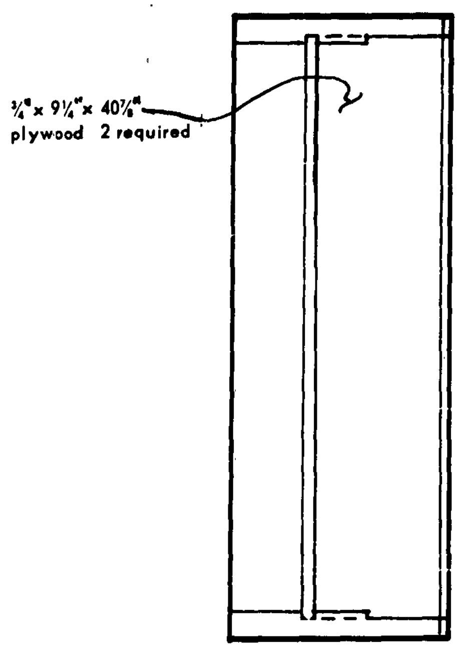
Hardwood Specialties Drawing No. HS 1004



Size: 43½" x 14½" x 108"

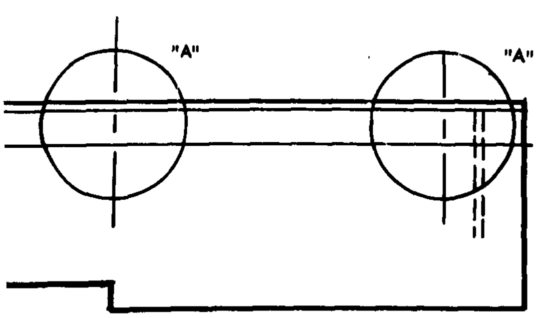
1





Packing Instructions

1. Place plywood in slots on each end
2. Place all door & wall sections in base
3. Put top on base & secure metal straps on each side.



PACKING INSTRUCTIONS
AIR LOCK

Hardwood Specialties Drawing No. HS 1100

ASSEMBLY INSTRUCTIONS
AIR LOCK

Hardwood Specialties Drawing No. HS 1101

1. Place packed unit on level area.

2. Remove metal straps on sides. (Leave on bottom bolts to be used in repacking)

3. Remove top assembly and all components from inside of base. Remove two plywood ends. (Save these for repacking)

4. Place center side panels (side notches 1/4" deep) on bolts in base, placing pass door on desired side. (Leave bolts loose)

5. Place center door panels in position with washers on outside of plywood. (Doors to swing in the direction of air flow)

6. Place end side panels in position. (3/4" notches to the end of unit) placing pass doors on desired side.

7. Place end doors in position. (Washers on outside of plywood) (Doors to swing in direction of air flow)

8. Place top assembly on unit. (Washers on inside of plywood)

9. Tighten all bolts.

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